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ABSTRACT

This guidebook for teachers is accompanied by a student workbook. The investigations are intended to offer students an opportunity to learn about the causes and effects of increases in the level of Lake Erie and the effects of lake level regulation. Illustrations and graphs accompany the written material. (Author/SA)

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OEAGLS - Oceanic Education Activities for Great Lakes Schools

LAKE ERIE AND CHANGING LAKE LEVELS

by

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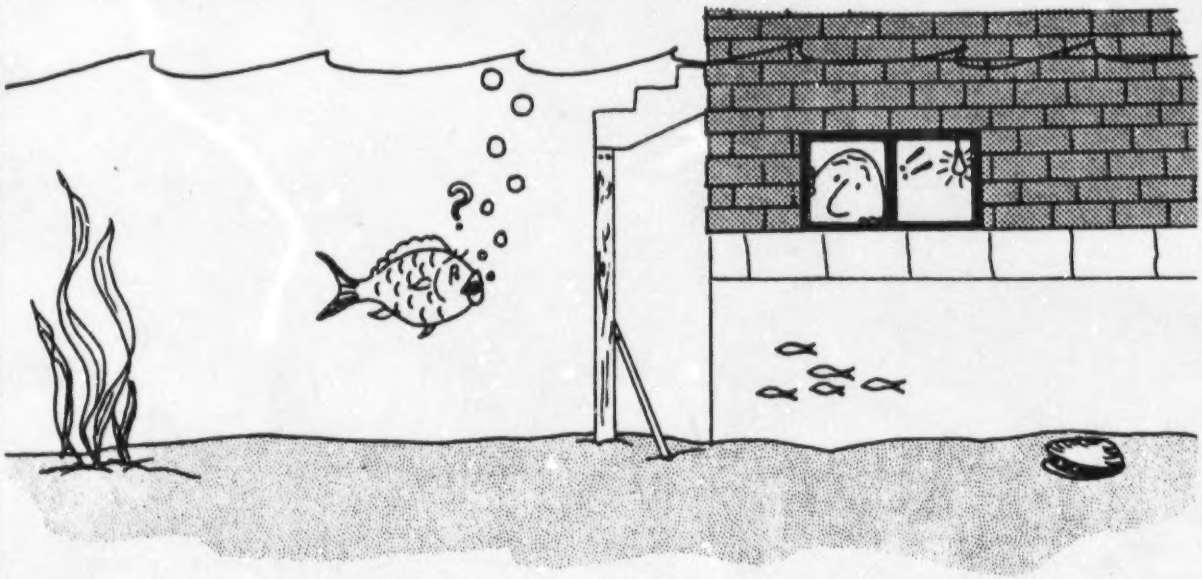

Ohio Sea Grant Program
Charles E. Herdendorf, Program Director
Victor J. Mayer, Principal Investigator

SE 028 771

OEAGLS INVESTIGATION 5

Completed March, 1979

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Figures 1,2,3,4, and 6 are from the International Joint Commission publication, Further Regulation of the Great Lakes.

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INVESTIGATION LAKE ERIE AND CHANGING LAKE LEVELS

INTRODUCTION People like lake shores. There is something about the movement of waves against the beach, the sight of a sailboat on a clear day, the ability to plunge into the water on a hot summer day, that attracts people to the lake. Shores tend to become highly developed. Property values are high. Lakes, however, can be unpredictable. Storm driven waves can destroy houses, especially if the level of the lake has risen since the houses were built. Is this a problem on Lake Erie?

OBJECTIVES When you have completed this investigation you will be able to:

1. Determine whether lake levels on Lake Erie change.
2. Determine the effect of an increase in lake level.
3. Identify possible causes of changes in lake level.
4. Identify the effects of regulating lake level on Lake Erie and the lakes connected with it.

ACTIVITY A DOES THE LEVEL OF LAKE ERIE CHANGE?

MATERIALS Topographic map of Eastlake, Ohio; graph paper, ruler and pencil.

PROCEDURE

Records of the level of the water in Lake Erie have been kept for over 100 years. Figure 2 on page 3 is a graph of the average monthly level of Lake Erie measured in feet above sea level. It includes the period from 1918 through 1975.

Figure 1 is a small section of that graph. It includes data for the years 1971-75.

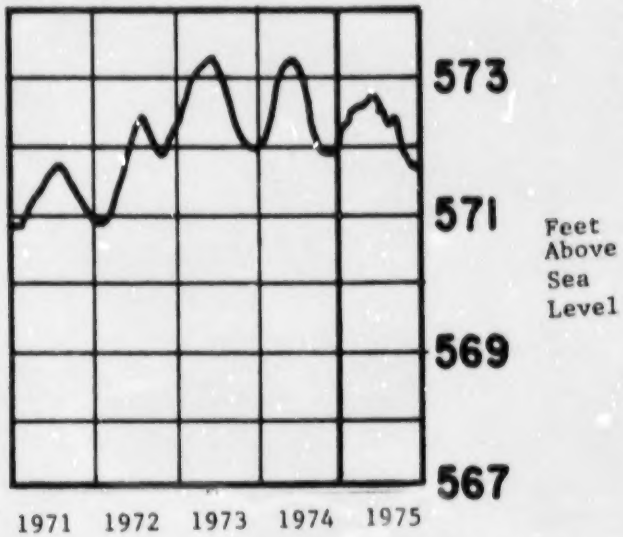


Figure 1: Lake Erie lake levels, 1971-1975

To answer questions 1-5 use Figure 1.

1. Determine the highest water level for 1974. What was it?_____

2. What was the lowest water level for 1974?_____

3. During what season of the year did the highest water level occur?_____The lowest water level?_____

4. What was the difference in feet between the lowest water level and the highest for 1974?_____

5. What could cause these differences in water level?_____

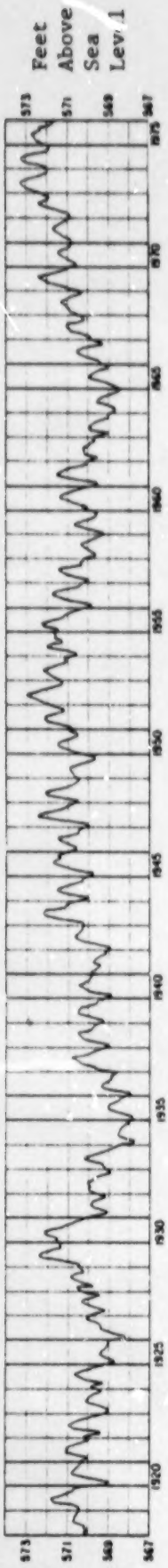


Figure 2. Monthly mean water levels of Lake Erie, 1918-1975

To answer questions 6-10 use Figure 2.

6. Is the yearly pattern of lake-level differences repeated in other years? If so, what do you think could cause such a yearly pattern?_____

7. In what year did the lake have the highest water level?_____How high was it?_____

8. In what year did the lake have the lowest water level?_____What was it?_____What is the difference between the highest and the lowest?_____

9. Do you notice other patterns in lake levels?_____ If so, how long do they seem to be?_____

10. Can you think of any possible reasons for these patterns?_____

You have found that the level of the lake does change. Do you think that such changes would be a threat to buildings along the shore?

To answer questions 11-16 you will work with a topographic map of an area of Lake County, east of Cleveland.

11. Locate the mouth of the Chagrin River. Draw a topographic profile of the area of houses on the north-east side of the river. Start in the lake. Draw the profile perpendicular to the shore, ending it near Jefferson School.

12. This map was drawn in 1963. Using Figure 2, determine the highest level of water that year. Plot this elevation on your profile.

13. According to Figure 2, what was the maximum height of the lake level in 1973?_____Plot this on your profile.

14. Do you think the change in lake level caused any flooding in the housing division?_____If so, where?_____

Actually, a great deal of damage occurred along the lake shore in the mid-1970's. It occurred during storms. Storms actually raise the lake level temporarily as in Figure 3. Strong winds blowing from the west across Lake Erie have raised the lake level as much as eight feet at Buffalo, New York.

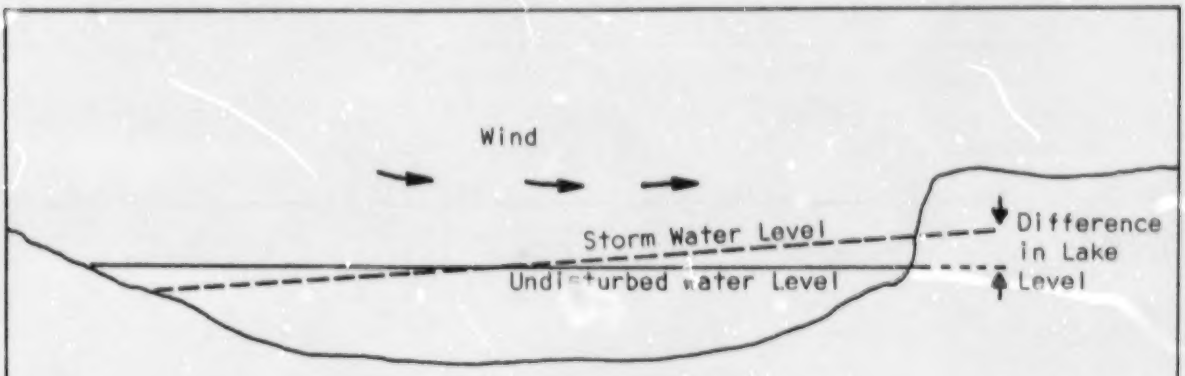


Figure 3. PROFILE OF A LAKE SHOWING EFFECT OF WIND ON LAKE LEVEL

15. If a storm occurring in 1973 raised lake level in the vicinity of the Chagrin River as much as three feet, how large an area would have been flooded?_____Remember the lake level determined in 13 above.

16. If the storm also caused four-foot high waves, how many houses might be damaged? _____

Most of the damage was actually the result of the erosion of cliffs along the lake. Storm waves cut at the base of the cliffs. They collapsed into the surf, taking any buildings along with them. In this way, higher lake levels have caused the shore of Lake Erie to move south.

On the Canadian (north) shore of the lake, erosion is three times as rapid. There are two reasons for this. The Canadian shore is largely underdeveloped farm land whereas the Ohio side is heavily developed with houses, ports, factories, etc. Buildings and other development tend to slow down the erosion process. Also, the wind tends to come more often from the southwest than from any other direction. This causes greater wave and current action on the Canadian shore.

ACTIVITY B WHAT WOULD BE THE RESULT OF REGULATING THE LEVEL OF LAKE ERIE?

MATERIALS Three plastic containers (lakes), a fourth container (precipitation device) and another to catch outflow.

PROCEDURE To reduce the problems of erosion, some people have suggested that the level of Lake Erie be lowered and maintained at a constant level.

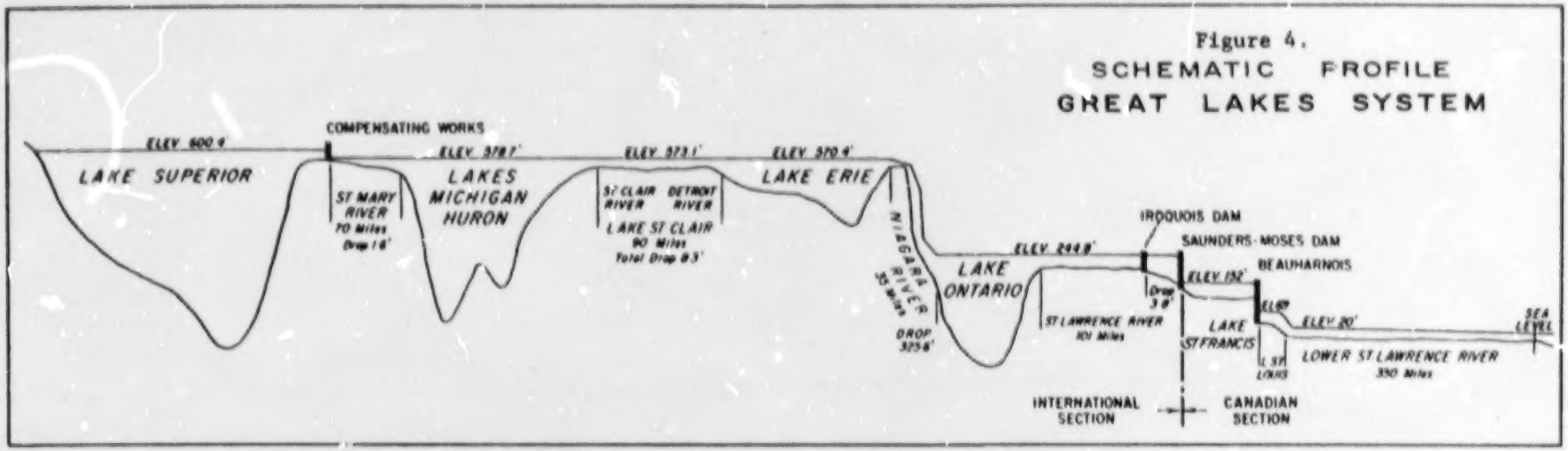
The flow of water into and out of Lake Erie could be controlled (regulated) through the use of dams and other devices. In this activity, you will study the effect of regulating the level of Lake Erie upon the levels of the lakes both upstream and downstream from Lake Erie (See Figure 4).

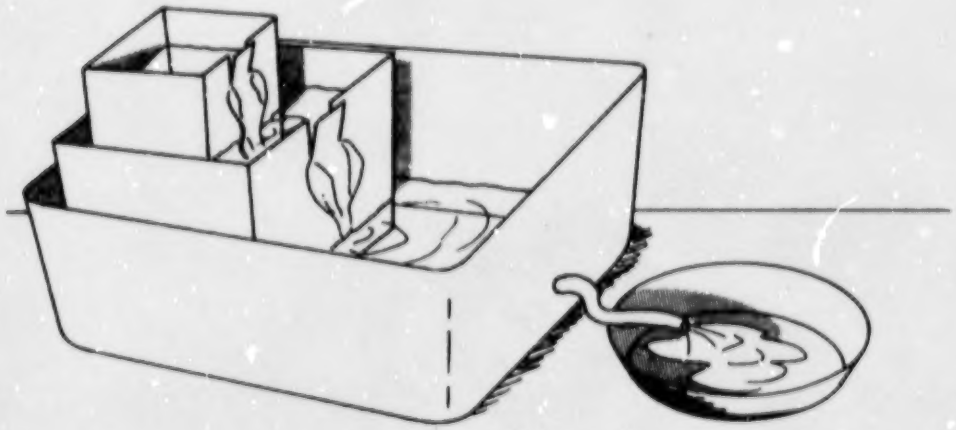
1. Set up your apparatus as in Figure 5. The tall plastic container will represent Lake Huron which is upstream from Lake Erie. The cut in the side of the container represents the outlet of the lake. Note that a piece of plastic has been left covering the slit. This can be either opened or closed, thus controlling the flow out of Lake Huron and into Lake Erie. Lake Erie is represented by a larger but lower container. It too has a slit in the side representing the outlet of the Lake. Lake Erie is sitting in an even larger container which represents Lake Ontario. The three containers together represent a model of the three Great Lakes.

2. Fill each of the lakes with water then wait until the lake level in each lake no longer changes. Mark this level on the outside of each container.

The level you marked is the level that would occur if no water ever entered or left any of the lakes. Of course this does not occur in nature. The level of each of the lakes at a given time will be determined by the amount of water entering the lakes and any variations in the rate of flow of this water through the lake system.

3. Be sure that the outlets of Lakes Huron and Erie are in the closed position. Some water should still be able to pass through the outlet. This position represents the way the lakes are naturally. The levels are not controlled by dams. Fill the precipitation container with water. The water in this container represents the fall of rain and snow (precipitation) into the lakes and the rivers that feed them. Pour this water into Lake Huron as rapidly as possible, without having any overflow the side of the lake. Mark on the side of each container the maximum lake level.





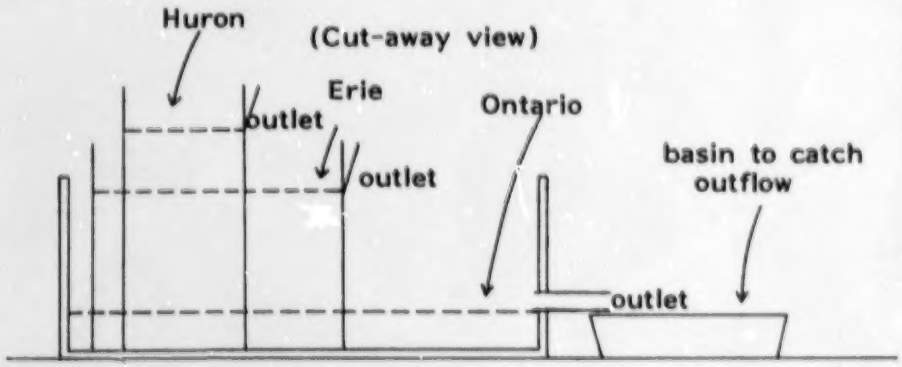


Figure 5. Model of three lakes. Dotted lines represent minimum lake levels.

4. Is the maximum (highest) lake level in all three lakes reached at the same time? Discuss.

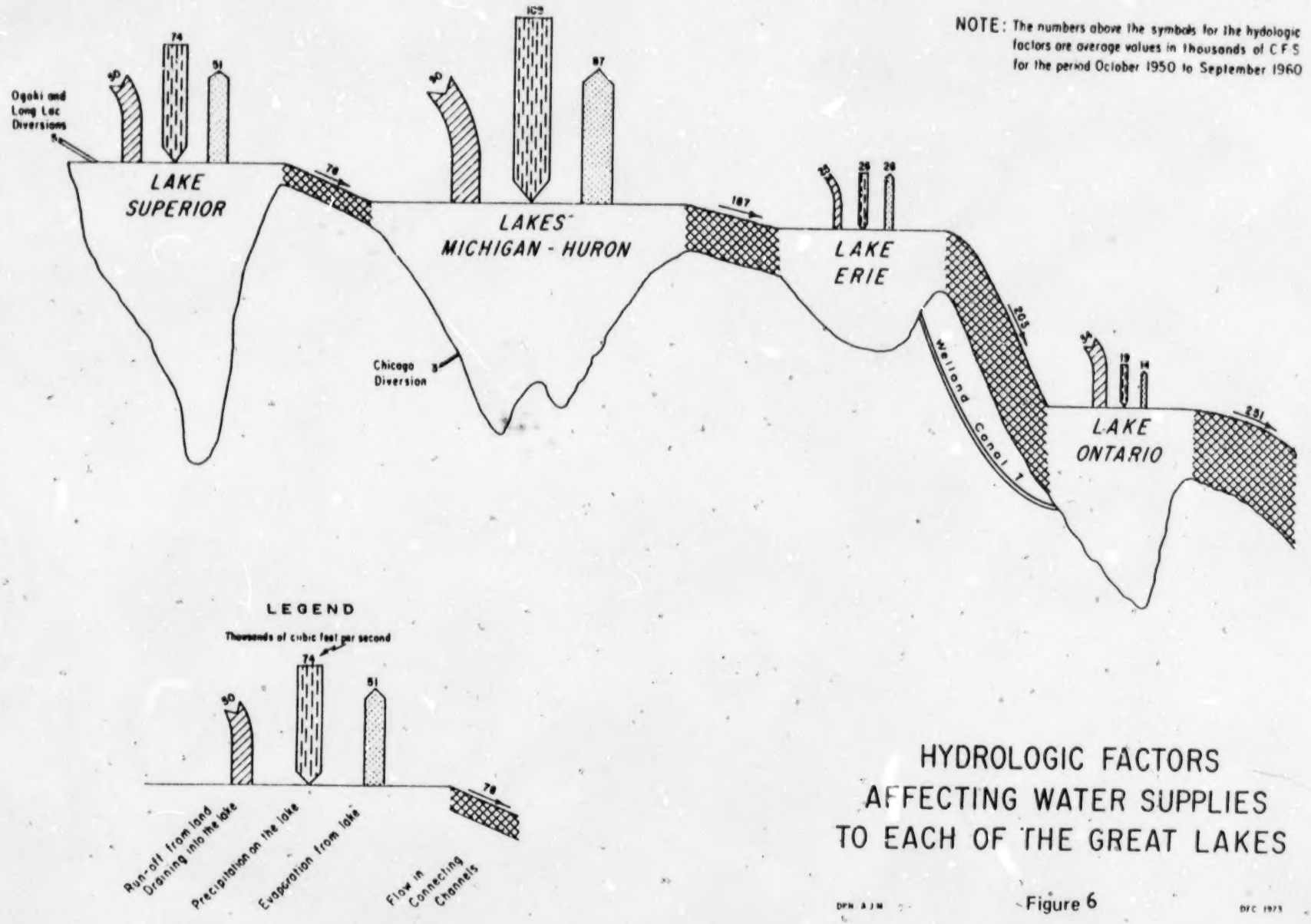
5. Fill the precipitation container again. Pour the water into Lake Huron more slowly than you did in Step 5. This represents a lower rate of precipitation than in Step 5. Mark the maximum lake level for each lake. Do the lakes reach as high a level when the rate of precipitation is less? Discuss.

6. Open the outlet of Lake Huron keeping Lake Erie closed. Repeat the procedure for the two different rates of precipitation. Describe what happens to the lake levels in Huron and Erie.

7. Now open the outlet of Lake Erie keeping Lake Huron open also and repeat the procedure for the same two rates of precipitation. Describe what happens to the lake levels of Huron and Erie.

8. What happens when only one lake at a time is regulated?

9. How would you design a regulation system that could keep Lake Erie's water level from raising or lowering too much or too fast?



HYDROLOGIC FACTORS AFFECTING WATER SUPPLIES TO EACH OF THE GREAT LAKES

Figure 6

Changes in lake level are thought to be due primarily to changes in the amount or rate of precipitation. These changes follow a yearly pattern (Remember your answers to Steps 1 through 6, Activity A). There also seems to be a longer term cycle. Perhaps you detected this in Figure 2.

In this activity you used a model of the lakes to investigate the effects of adding precipitation to lakes upstream from Lake Erie. The flow-through of that precipitation changed lake levels downstream. In nature, the situation is more complicated because precipitation will be added to all of the lakes directly through run-off from rivers and streams entering the lakes. Figure 6 illustrates the relative importance of each source of water for each of the lakes. Any program to regulate the level of Lake Erie must take into account all sources of water and their possible effects on lake level.

REVIEW QUESTIONS

1. How much has the level of Lake Erie changed over the past 57 years?

2. What patterns or cycles are there in the changes in the level of Lake Erie?

3. What have been some of the effects of an increase in the level of the lake?

4. What causes the level of the lake to change?

5. How could the level of the lake be regulated?

6. What effects would regulating Lake Erie have upon the other lakes in the Great Lakes system?

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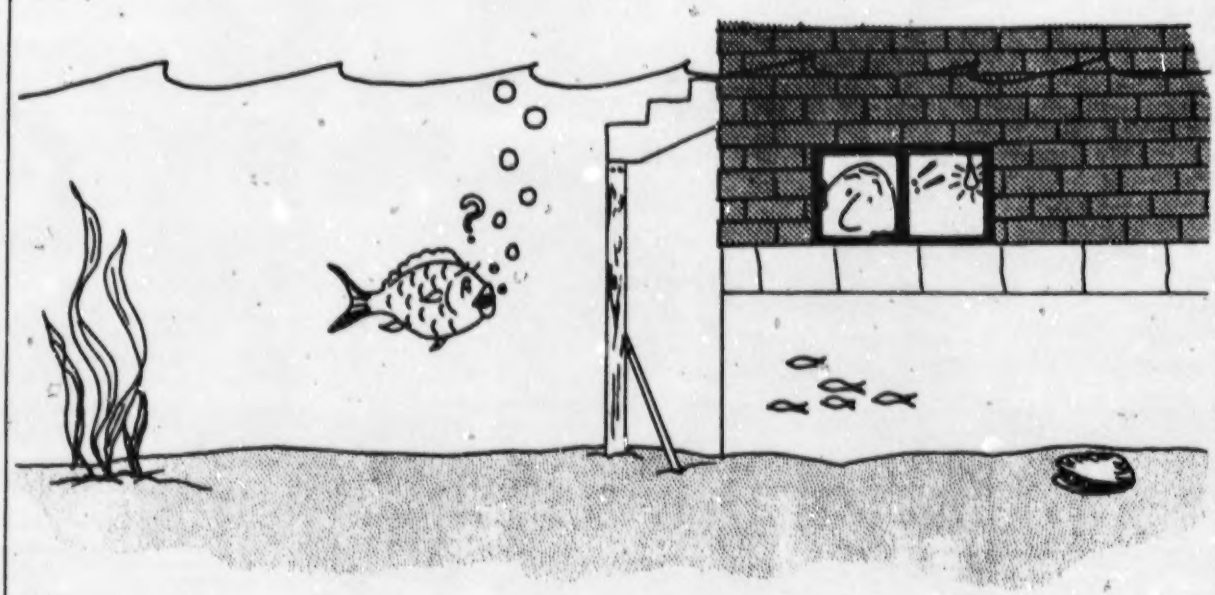

Ohio Sea Grant Program
Charles E. Herdendorf, Program Director
Victor J. Mayer, Principal Investigator

TEACHER GUIDE

OEAGLS INVESTIGATION #5

Completed April, 1979

This instructional activity was prepared with the support of National Oceanic and Atmospheric Administration Grant Nos. 04-158-44099 and 04-8-M01-170. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the authors, and do not necessarily reflect the views of NOAA.

Figure TG 1 is from the publication Further Regulation of the Great Lakes of the International Joint Commission.

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INVESTIGATION — LAKE ERIE AND CHANGING LAKE LEVELS

OVERVIEW

In Activity A students determine how the water level in Lake Erie has changed over the years since 1918. This is accomplished by examining a graph of Lake Erie mean water levels. Their attention is drawn to the cyclic nature of lake level changes and the damages that can occur when the lake level rises. The effect of storms on lake level is also explored.

In Activity B students study possible results of regulating the lake's water level and the role of precipitation in causing changes in lake level.

PREREQUISITE STUDENT BACKGROUND

Students should be able to read graphs and topographic maps and draw topographic profiles.

MATERIALS

Topographic maps of Eastlake, Ohio; graph paper, rulers, pencils. For each lab group: three plastic containers of various sizes (lakes), a fourth container to catch overflow and a fifth for a precipitation device. (See Figure 4 of the Student Guide.)

OBJECTIVES

When the students have completed this investigation they should be able to:

1. Determine whether lake levels on Lake Erie change.
2. Determine the effects of an increase in lake level.
3. Identify possible causes of changes in lake level.
4. Identify the effects of regulating lake level on Lake Erie and the lakes connected with it.

SUGGESTED APPROACH

Activity A should be done individually with two students sharing one topographic map.

Activity B should be completed in groups of 3. One student should read the instructions, one operate the equipment and the third observe and report data.

Introduce the Investigation by a discussion with your students related to points raised in the Introduction to the Student Guide. Additional information can be obtained from the reference included at the end of this guide. You should also conduct a post-investigation discussion. Be sure that the points included at various places in the Student Guide are understood.

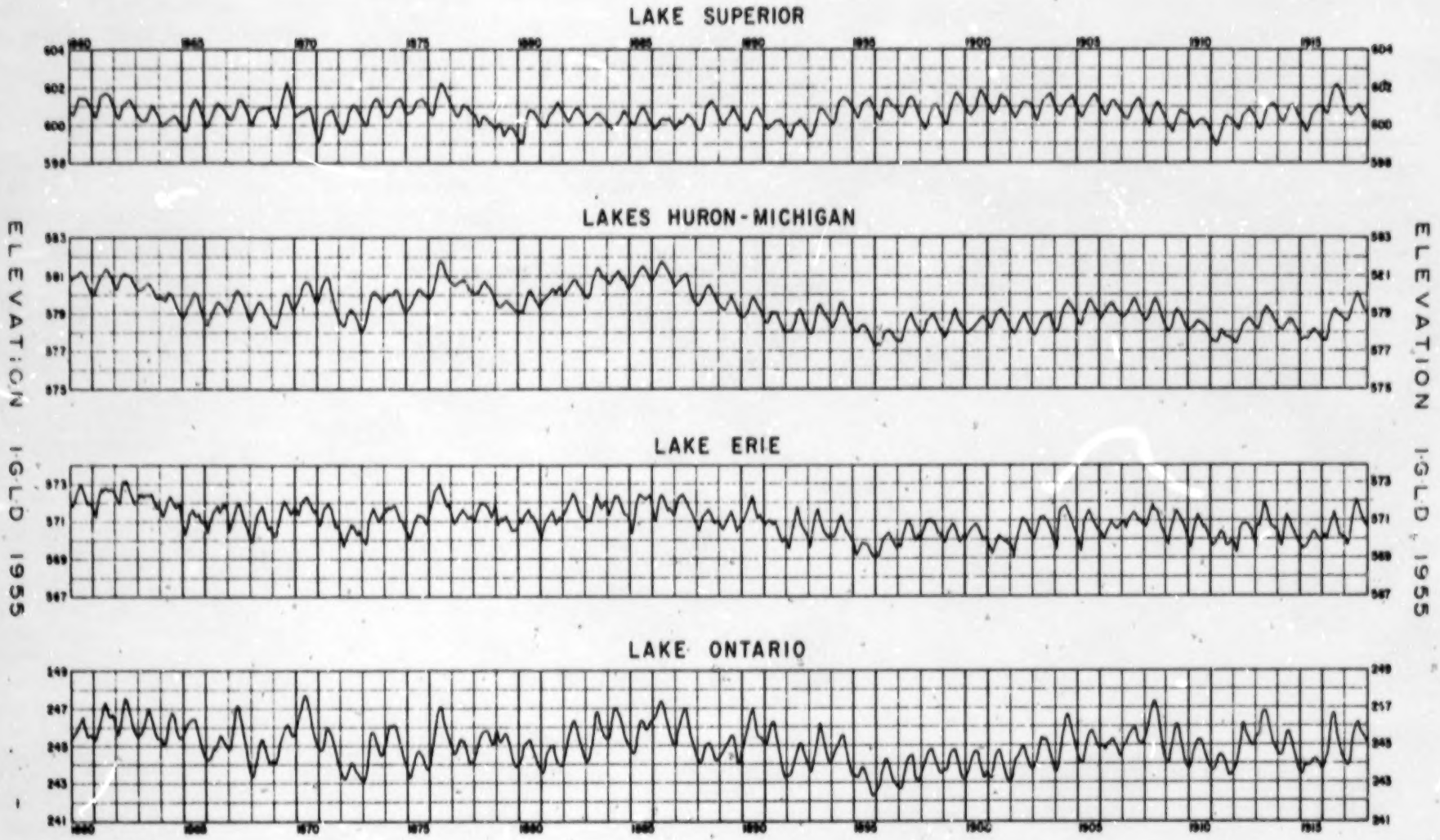
The film "Not Man's to Command" is available through the Public Relations Unit, Canada Centre for Inland Waters, P.O. Box 5050, Burlington, Ontario, L7R 4A6. It deals with many of the problems in trying to regulate the Great Lakes. If available, it should be shown as a follow-up to the Investigation.

ACTIVITY A — DOES THE LEVEL OF LAKE ERIE CHANGE?

PROCEDURE

In this activity students learn of the cyclic nature of lake levels on Lake Erie, the effect of wind in setting up the lake and the combined effects of the two processes in producing flooding in an area of Ohio.

1. 573.2' above sea level
2. 572.0' above sea level
3. Highest water level occurred in spring and the lowest in winter.
4. 573.2' - 572.0' = 1.2'
5. Variations in lake levels are due primarily to changes in the amount or rate of precipitation. Note that late winter tends to be a time of low lake level. Precipitation is relatively light at that time of the year, and any that does fall is likely to be held either in the snow pack, or as frozen ground water. During the spring the combination of run-off from the winter and high precipitation tends to produce high lake levels.
6. The pattern of lake level differences is repeated in other years, but not always as clearly as for 1974. The reason for this pattern is discussed above.
7. The highest water level occurred in 1973 and 1974. It was 573.2 feet above sea level.



MONTHLY MEAN WATER LEVELS OF THE GREAT LAKES 1860-1917

Figure TG 1

12. The highest water level in 1963 was 570 feet above sea level.

13. The highest level in 1973 was just over 573 feet above sea level.

14. It would appear from the plot on the profile that this three-foot rise in lake level was not enough to flood any of the housing development. The higher lake level, however, would have increased the rate of erosion of the beach and the adjacent cliffs. This would have resulted in undermining the cliffs, landslides, and the accompanying destruction of property.

15. A storm occurring in 1973 would have raised the lake level to 576 feet, or more. Therefore, during a storm extensive flooding could, and did, take place as far back as the slight rise northwest of the roads.

16. High waves accompanying the storm would do a great deal of damage over that area. In fact, this was an area that sustained a great deal of damage during the summer of 1973. Students could count the number of houses in the flat area adjacent to the mouth of the river. There are well over 100. Not all of them, however, actually sustained damage.

ACTIVITY B — WHAT WOULD BE THE RESULT OF REGULATING THE LEVEL OF LAKE ERIE?

The purpose of Activity B is to explore the effect controlling the level of Lake Erie has upon the levels of the Great Lakes.

Questions 1-3. The set-up and preliminary experiment procedure.

Set the apparatus up ahead of time to test it. You will then know that each set-up is working so that the students can complete the procedures on their own with minimum supervision from you.

4. Maximum lake levels were not reached at the same time. "Lake Huron" overflows first, then "Lake Erie," then "Lake Ontario." The lag is a function of the flow-through time needed for the water to move from "Lake Huron" to "Lake Ontario."

8. The lowest water level occurred in 1934. It was 567.9 feet above sea level. The difference between the highest and the lowest is 5.3 feet.

9. There does seem to be about a 20 to 25 year pattern. It is repeated twice between 1928 and 1952 and between 1952 and 1973. Figure TG 1 is a graph of lake levels between 1860 and 1917. Note that this 20 to 25 year pattern does not seem to persist. You might use this as an example to your students of the dangers of making generalizations based upon limited data.

10. The longer term variations, though they may not be cyclic, did occur. They are probably related to changes in overall climate in the Great Lakes region.

Students use the 15' quadrangle of Eastlake, Ohio, for this part of the activity. They will find the light (5') contour lines very difficult to read in the portion of the map they are using. In fact, in places the lines converge. It is not important that they locate each line. They should note that the lines tend to group close to the heavier contour lines. They can draw the profiles accordingly.

11. See Figure TG 2 for a completed profile. Students should be careful not to use too great a vertical exaggeration; 100 to 150 feet to the inch would be appropriate. The heavy contour line close to the lake shore is the 575 foot line.

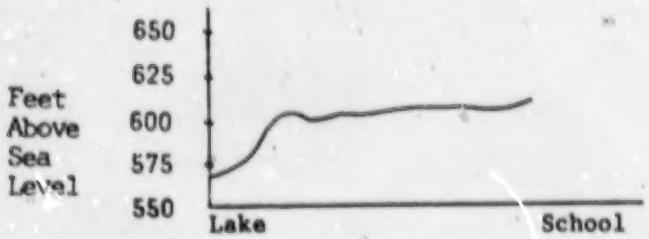


Figure TG 2

5. With the lower rates of precipitation, lake levels do not rise to as high a maximum level. This is analogous to what happens in nature. Help students to tie this to their answer to question 6 of Activity A. They should realize that lake levels are related to the rates of precipitation.

6. Opening the outlet to Lake Huron results in more rapid flow through of the precipitation and thus a lower maximum level in Lake Huron and higher maximum lake levels in Lake Erie.

7. The maximum lake levels reached in both lakes should be lower than when both outlets were closed. Therefore, by producing an increased outflow in both lakes their maximum lake levels would be reduced.

8. In this model, students regulate a lake only by increasing the outflow of water. In this case, then, introducing regulation in one lake caused higher lake levels in the lake downstream. In reality, the outflow from a lake can also be reduced by closing dams thereby reducing lake level downstream.

9. You should accept any reasonable answer. Systems of dams and deepened and widened channels are most commonly used in regulating lake level.

REVIEW QUESTIONS

1. The maximum difference in water levels since 1918 has been about 6.3 feet.

2. The Lake Erie water level has had cyclic changes over the time that water level records have been kept. There is a seasonal cycle and there may also be a much longer cycle of about 25 years.

3. Increased lake levels have caused flooding and increased shore erosion. The flooding and erosion have had significant economic impact on shoreline homes, and on businesses and recreation areas.

4. Short term changes in lake level are caused by wind. Annual changes are caused by variations in the amount of precipitation.

5. Lake levels could be regulated by increasing the outlet size and thereby increasing the possible outflow or by damming the upstream lake in order to precisely regulate the amount of water flowing in.

6. The damned upstream lake(s) would experience increased flooding and shore erosion, while the downstream lake(s) would tend to have a more consistent water level.

BACKGROUND INFORMATION

The two major causes of changes in the levels of the lakes are wind set-up and changes in precipitation. Wind set-up is caused by the persistent blowing of wind in a single direction over a prolonged period of time. This causes a "piling up" of water at the downwind end or side of the lake. Wind set-up tends to have a short range effect on lake level and can produce daily variations. Changes in the amount and rate of precipitation have longer range effects on lake level. In Activity A, students discover annual variation which is due to precipitation. There are longer cycles that are undoubtedly also related to precipitation and in turn to climatic fluctuations in the drainage basin of the Great Lakes.

Lake Erie lake levels could be regulated by controlling the outflow through the Niagara River and/or by controlling the inflow from Lake Huron through the Detroit River. A channel would have to be constructed around the Niagara gorge to carry the necessary outflow during high water seasons. This increased outflow could increase the level of Lake Ontario, causing damage, or if it were passed rapidly through Ontario, it could cause damage on the floodplain of the St. Lawrence River. Controlling the amount of inflow, conversely would raise the level of Lake Huron and cause damage there. To effectively modify the level of Lake Erie, then, the entire Great Lakes system would have to be controlled. This would be terribly expensive. In 1976, the International Joint Commission recommended against this because of the high cost and relatively low benefits.

During the 1950's a series of dams and channels was constructed on the St. Lawrence River at the outlet of Lake Ontario. Beginning in 1960 these structures were used to regulate the lake levels in Lake Ontario. Between 1960 and 1974 the level of the lake varied between a low of 241.7 and a high of 247.9; a range of 6.2 feet. If regulation had not occurred, lake level would have varied between 241.4 and 249.1; a range of 7.7 feet. Lake Superior is also regulated. A series of structures that modified the amount of outflow from Lake Superior had been built in the

St. Mary's River starting in the late 1800's. In 1921 a systematic plan for the regulation of the lake was implemented.

As noted in this activity, the years 1973 and 1974 were high level years in Lake Erie. The other lower lakes also experienced high waters in those years. To help control this problem, the outflow from Lake Superior was reduced. This would be an actual application of the ideas modeled in the second part of this Investigation.

REFERENCES

International Joint Commission, Further Regulation of the Great Lakes, 1976. Figures 1,2,3,4, and 6 are adapted from this publication. It provides a good overview of the history, mechanisms, and potential benefits of regulating the Great Lakes.

The March, 1979 issue (Vol 9, #6) of the Great Lakes Communicator is devoted to lake level regulation and shore damage studies. It provides excellent background information for this activity. It is published by the Great Lakes Basin Commission, Box 999, 3475 Plymouth Road, Ann Arbor, Michigan 48106.

EVALUATION ITEMS

1. In general, the highest yearly lake levels in Lake Erie occur in

    1. almost any season of the year.
    2. fall.
    *3. late spring or summer.
    4. winter.

2. The most likely cause of seasonal changes in lake level is

    1. rate of evaporation.
    2. regulation of the lake.
    3. erosion of the outlet of the lake.
    *4. precipitation.

3. An increase in the level of Lake Erie helps to cause

    1. migration of waterfowl.
    *2. destruction of shore property.
    3. deposition of beaches.
    4. an increase in precipitation.

4. Which of the following contributes to the destruction of shore property along Lake Erie?

   *1. waves.
   2. pollution of lake water.
   3. increased use of beaches for recreational purposes.
   4. regulation of the lake.

5. Small temporary (day or two) changes in lake levels can be caused by

   *1. high winds blowing in a single direction.
   2. regulating the level of the lake.
   3. changes in the number of ships in the lake.
   4. changes in the rate of precipitation over the lake.